TREND OF AIRBORNE PARTICULATE LEAD IN ONTARIO: 1971-1978

Ontario

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Abstract:

Measurements of airborne particulate lead in Ontario during the period 1971-1978 show an increase in average lead concentration during the period 1971 to 1972 and a decrease amounting to 59% from 1972 to 1978. Average lead concentrations measured at four sites adjacent to an expressway show a similar downward trend. During the same period, total gasoline consumption rose while the amount of lead in gasoline declined from 1973 to 1978 by 49%. The decrease in lead concentrations and lead consumption correlated well (r^2=0.95).

Introduction

Because of its many useful properties, lead has been utilized by man in his industry since antiquity. The health hazards of this metal have also long been recognized. The concern over these hazards focused, during the 19th and 20th century, on mortality due to lead poisoning. With the near elimination of lead poisoning as a cause of death in the past two decades, attention has now been turned to the insidious health effects of exposure to lead. (1)

Much of the aerosol lead found in the atmosphere in recent years has resulted from the combustion of gasoline containing lead additives. (In Ontario, for example, 68% of the 1970 estimated lead emissions were due to automotive sources (2)). Since 1972, however, there has been a reduction in the lead content of leaded gasoline and, in 1975, unleaded gasoline was introduced. By 1978, unleaded gasoline comprised 28% of the gasoline sales in Ontario (3).

Although unleaded gasoline was mainly introduced because of the requirement of catalytic converters in the exhaust system for unleaded fuel, the result of its usage, along with the reduction of the lead content in leaded gasoline, has been to reduce the quantity of lead emitted in Ontario in 1978 to 51% of the 1970 emissions (3).

The Ontario Lead Monitoring Network

In order to monitor ambient airborne lead concentrations, the Province of Ontario established a lead monitoring network in 1969 at a limited number of locations. In 1971, fifteen sites collected a sufficient number of samples to establish an annual geometric mean. By 1978, this network had expanded to 68 such sites, of which 14 comprised a special intensive survey in the vicinity of several lead processing plants.

Particulate matter was collected at each site on glass-fiber filters by the standard high-volume sampling method, and samples were analyzed for lead by

either atomic absorption spectroscopy or x-ray fluorescence measurement techniques.

For the statistical analysis made in this report, only those stations with five samples per quarter were used to calculate an annual geometric mean. Stations from the special intensive survey surrounding the lead-processing plants which began in 1973 were not included in the ensemble from which statistics describing the general lead concentration in Ontario were drawn.

Airborne Lead in Ontario

The averages of the annual geometric mean for particulate lead in Ontario for the years 1971 to 1978 are given in Table I along with the range of the annual geometric means in the network. As is seen, there is a steady decrease in the annual average from 1972 to 1978. In order to determine the significance of this trend, the data were further analyzed using the Wilcoxon Matched-Pairs, Signed-Ranks Test (4). The results of this test (Table II) show the downward trend was significant to the 98 or 99 percentile for the years 1973-1978. (Too few pair were available to determine significance for the periods 1971-72 and 1972-73).

Since automotive emissions are the most important sources of lead in Ontario, it is reasonable to assume that there would be a positive correlation between measured lead concentrations and automotive lead emissions. Data were obtained from Ethyl Canada Inc. (3) of the annual gasoline sales in Ontario, the annual leaded gasoline sales, and the average lead content of the leaded fuel (Table III). From these figures, the annual lead consumption (taken as the product of leaded gasoline consumption and average lead content) was calculated. It must be realized, however, that only about 35% of the lead consumed is emitted as fine particles (under 5 um in size).

Four of the lead-monitoring sites are located close to major expressways. The annual geometric means of lead at these sites (Table IV) show a similar, and

for two sites dramatic, downward trend in lead concentrations from 1974 to 1978.

The annual average concentrations for the network and the four expressway sites have been plotted in Figure 1 along with the annual lead consumption. All three curves show a similar pattern: a steady decrease from 1973 to 1978. Prior to 1973 there had been a rise in lead consumption and average lead concentrations. Total gasoline sales, on the other hand, showed a steady increase during the 1971-78 period (Table I).

In order to more readily compare the trends in measured lead concentrations, lead emission, and gasoline consumption over the period the data were normalized by the 1971 value. A linear regression between the components resulted in the relation

$$X_N = -.56 + 1.45\, Q_N \qquad (1)$$

with r^2 =0.92 (significant at 99 percentile),

and

$$X_N = 3.34 - 2.16\, G_N \qquad (2)$$

with r^2 = 0.65 (significant at 99 percentile),

where X_N is the normalized lead concentration, Q_N is the normalized lead emissions, and G_N is the normalized gasoline consumption (leaded plus unleaded).

The strong correlation shown in (1) makes it reasonable to assume that the decrease in measured lead concentrations was due to a decrease in lead consumption by automobiles. The relationship between measured lead and gasoline consumption, on the other hand, shows a negative correlation, indicating that the decrease was not due to a decrease in total gasoline consumption.

The concentration of lead measured on a given day is influenced by a number of factors such as the quantity of lead emitted, meteorological factors such as wind speed, and traffic factors such as traffic volume near the monitor.

The Province of Ontario has set as its criterion for the maximum desired concentration of lead in ambient air for a 24-hour sampling time 5.0 ug/m^3. While both the emission of lead and weather are influencing factors on daily concentrations, it is interesting to note the effect of the aforementioned emission reductions on the number of samples exceeding the criterion. During the period 1971 to 1975, the number of days on which the 5.0 ug/m^3 concentration was exceeded ranged from 26 to 42 times per year in the full monitoring network (excluding those stations around lead industries). In comparison, during the years 1976 to 1978, the number of days on which the criterion was exceeded ranged from 2 to 9 occasions per year.

Conclusions

The trend in measured lead concentrations during the period 1971 to 1978 shows a significant decrease from 1972 to 1978 amounting to 59%. Lead concentrations at four expressway sites also showed an average decrease of 59% from 1973 to 1978. Lead from gasoline emitted as fine particles has decreased since 1973 by 49%. During the same period (1973-78), gasoline consumption rose by 10%. It is therefore concluded that the decrease in lead concentrations was due to the decrease in the lead content in leaded gasoline and the increased usage of unleaded gasoline.

The number of days on which the Ontario criterion for lead of 5.0 ug/m^3 was exceeded dropped from between 26 and 42 days annually during the 1971-1975 period to between 2 and 9 days annually for the period 1976-1978.

References

(1) Chant, D.A., F.A. DeMarco, and H.R. Robertson, 1974: Effect on Human Health of Lead from the Environment, Ontario Ministry of Health, Toronto, 108 pp.

(2) The Working Group on Lead, 1974: Studies of the Relationship of Environmental Lead Levels and Human Lead Intake, Ontario Ministry of the Environment, Toronto, 407 pp.

(3) Personal Communications, D.N. Brown, J.M. Collins, and J. Thompson, Ethyl Canada, Inc., 1979.

(4) Conover, W.J., 1971: Practical Nonparametric Statistics, John Wiley & Sons, Inc., Toronto. 462 pp.

TABLE I

Average Annual Concentration of Airborne Particulate Lead in Ontario

	Year							
	1971	1972	1973	1974	1975	1976	1977	1978
Average of Annual Geometric Means (ug/m^3)	0.99	1.11	1.03	0.96	0.81	0.72	0.50	0.46
Range of Annual Geometric Means (ug/m^3)	0.5-1.7	0.3-3.5	0.2-3.5	0.1-3.6	0.2-2.7	0.2-2.0	0.2-1.7	0.1-1.2
Standard Deviation of Annual Geometric Means (ug/m^3)	.38	.95	.78	.84	.63	.52	.33	.26
Sample Size	15	19	25	22	21	23	20	54

TABLE II

Trend of Particulate Lead in Ontario

Years	Number of Stations	Number of Stations Decreasing	Number of Stations Increasing	No Change	Trend	Significance Level
1971-72	5	5	0	0	-	-
1972-73	10	3	2	5	-	-
1973-74	15	13	1	1	Decrease	99
1974-75	15	9	1	5	Decrease	99
1975-76	16	10	1	5	Decrease	99
1976-77	16	10	2	4	Decrease	99
1977-78	15	9	2	4	Decrease	98

TABLE III
Lead Consumption Due to Gasoline Usage in Ontario

Year	Annual Sales of Leaded Gasoline (10^6 Imp. Gal.)	Total Sales of Gasoline (10^6 Imp. Gal) G	Average Lead Content of Gasoline (gPb/Imp. Gal) L	Lead Consumed (10^9 g Pb) LG	Lead Emitted as Fine Particle (10^9 g Pb) .35LG
1971	2224.0	2224.0	2.47	5.49	1.92
1972	2335.9	2335.9	2.61	6.10	2.14
1973	2539.7	2539.7	2.52	6.40	2.24
1974	2612.2	2612.2	2.27	5.93	2.08
1975	2509.5	2681.1	1.93	5.18	1.81
1976	2341.0	2706.4	1.84	4.98	1.74
1977	2168.7	2734.8	1.59	4.35	1.52
1978	2027.1	2800.1	1.36	3.81	1.33

TABLE IV

Lead Concentrations at Stations Adjacent to Expressways

Station	Distance to Expressway(m)	Annual Geometric Mean Lead Concentration (ug/m^3) 1972	1973	1974	1975	1976	1977	1978
29008	20	-	1.4	1.3	1.1	0.9	0.8	0.8
33002	16	3.5	3.5	3.6	2.1	2.0	1.7	0.9
34007	32	-	2.8	2.7	2.7	1.5	1.5	1.2
35033	101	2.2	1.8	1.7	1.4	1.4	1.2	1.0
Average Of 4 Stations		-	2.38	2.33	1.83	1.45	1.30	0.98

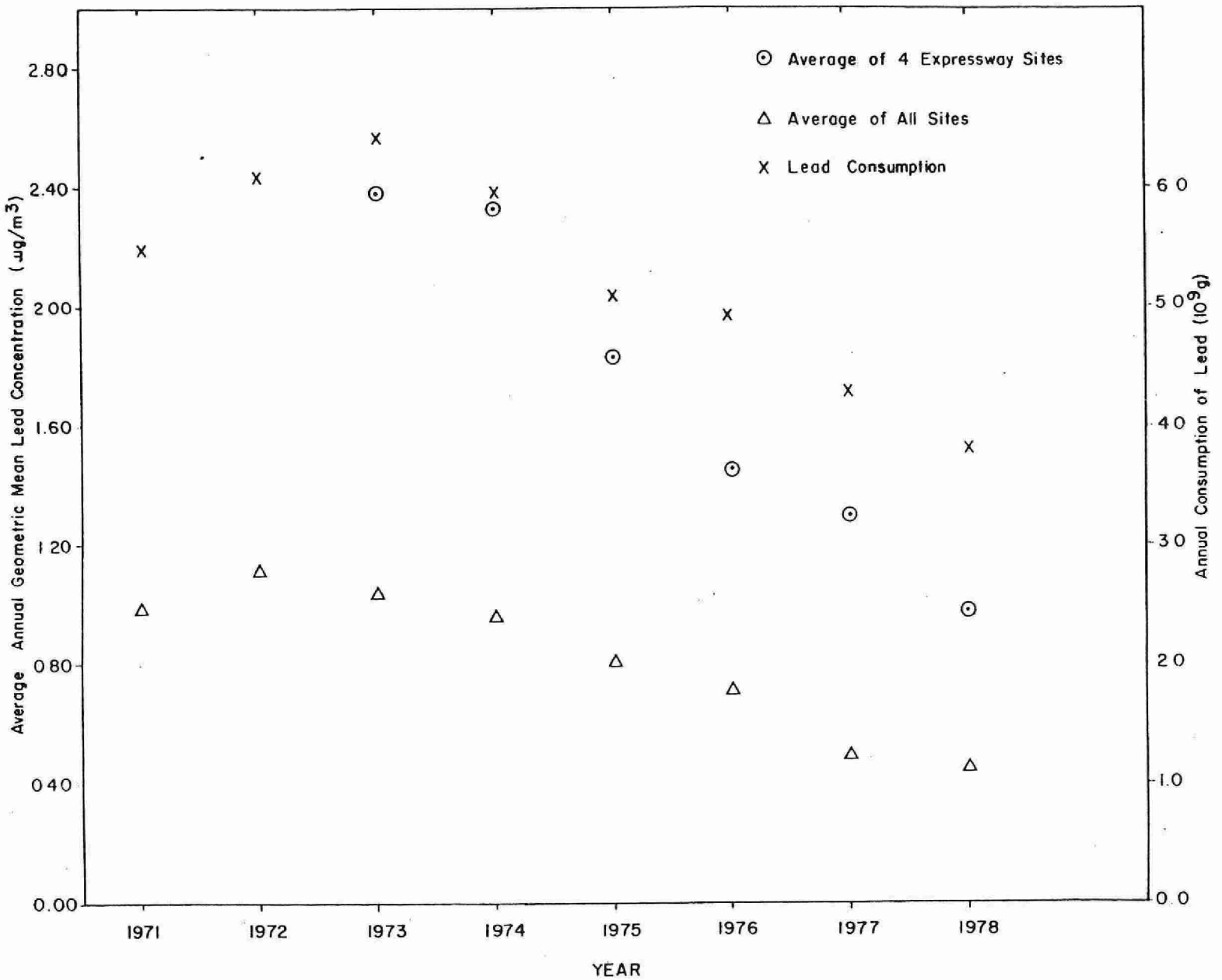

Figure 1: Average annual lead concentrations (ug/m^3) and lead consumption ($10^9 g$) for the period 1971-1978.